Characterizing Contaminants of Emerging Concern in Lake Sturgeon Tissues and Implications for Management

Emerging Contaminants in the Environment Conference 2021

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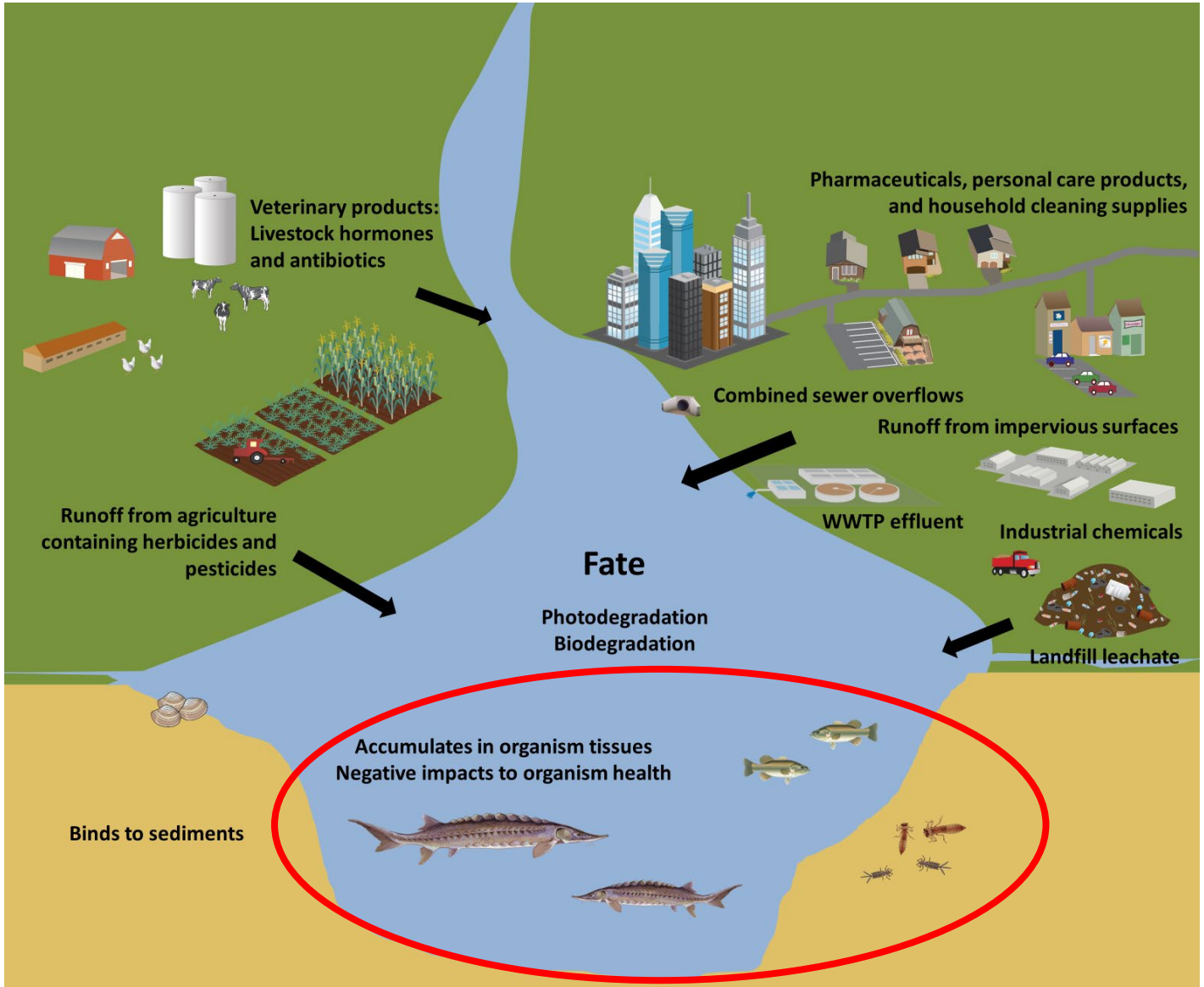
DEPARTMENT OF THE INTERIOR

Great Lakes RESTORATION

Outline

- Why lake sturgeon?
- Objective
- Methods
- Results and Discussion
- Conclusions and management implications

Sources and fate of CECs



Symbols used in conceptual model (with the exception of lake sturgeon) courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/)

Why lake sturgeon?

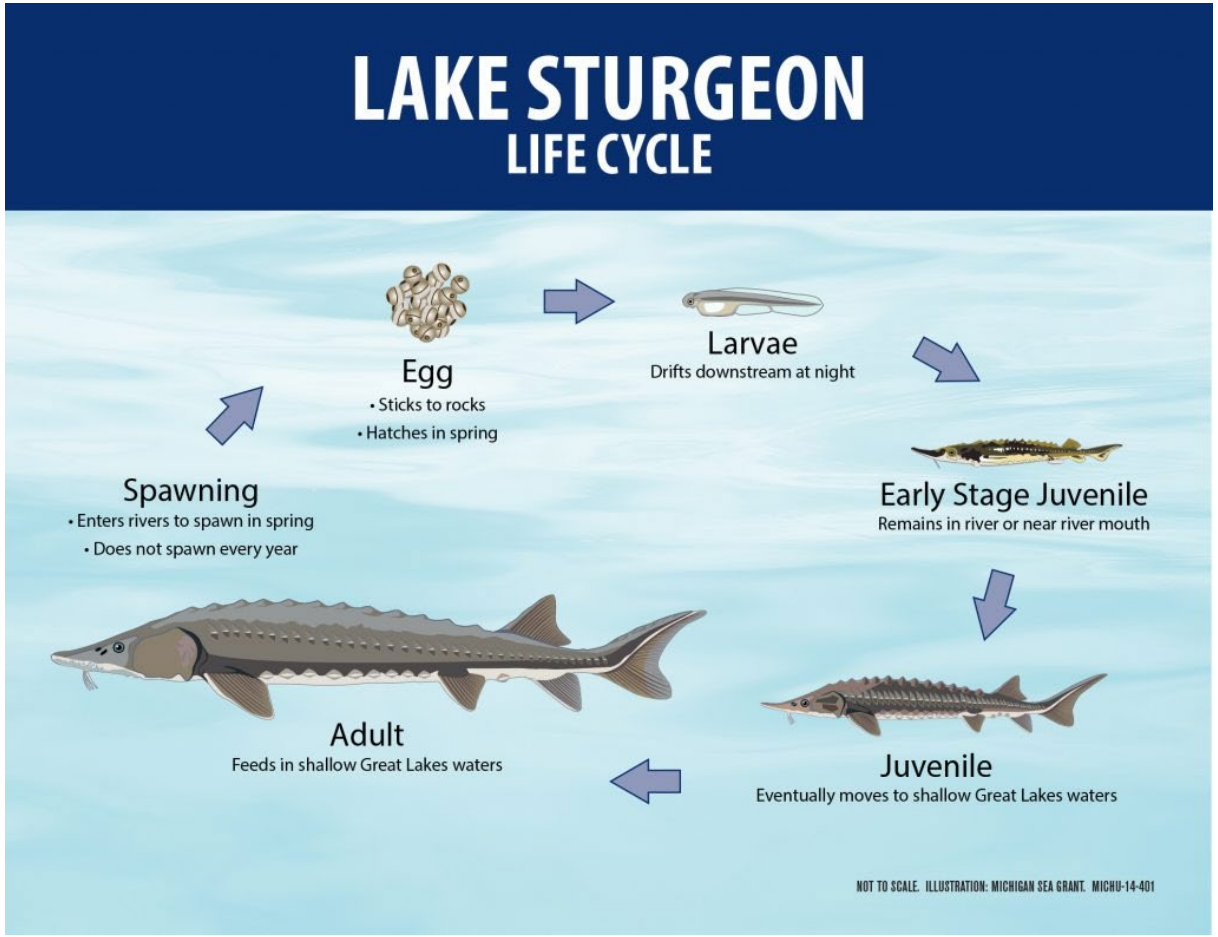
- Limited understanding of biological effects in organisms associated with CEC exposure but some evidence of physiological effects to fish and other wildlife (Jasinska et al. 2015, Hicks et al. 2017, Thomas et al. 2017, Cipoletti et al. 2017) → imperiled and recovering species?

- Lake sturgeon are listed as state endangered, threatened, or a species of special concern in all Great Lakes states where they occur

- Overexploitation, loss of habitat, invasive species, and exposure to contaminants have led to massive declines → large recovery effort across the Great Lakes

Lake sturgeon biology

- Unusual life history
  - Long-lived (up to 150 years) → potential for long term exposure to CECs
  - Late maturity (>14 and >20 years for males and females, respectively) → could mask growth, development, or reproductive effects
  - Migratory → multiple locations and environments
- Diet: benthic feeders; primarily invertebrates and small fish → dietary exposure
- No existing literature about CEC-associated effects in long-lived, late maturing species and potential for population level effects



Michigan Sea Grant
https://www.michiganseagrant.org/topics/ecosystems-and-habitats/native-species-and-biodiversity/lake-sturgeon/

Objective

- Characterize the CECs (PPCPs and PBDEs, specifically) in adult lake sturgeon tissues (serum and gametes) and their potential effects (based on available literature) in order to inform natural resource managers working to protect and conserve lake sturgeon.

Methods

- Lake sturgeon captured at 4 locations where spawning is known to occur in the lower Great Lakes: Detroit River, upper and lower Niagara rivers, and St. Lawrence River

- Sex determination
  - Direct expression of gametes
  - Direct observation of gonads – surgical implantation of acoustic transmitters
  - Externally via ultrasound

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Methods, cont'd

- Blood drawn from caudal vasculature and serum extracted
- Gametes (eggs and milt) collected at the St. Lawrence River location only
- Serum and gamete samples submitted to SGS Axys Analytical Laboratory for determination of PPCP and PBDE concentrations

Statistical analyses

- Only contaminants detected in at least 25% of samples from at least one site considered for analyses
- Maximum concentrations of chemicals determined; for some chemicals concentrations were compared across sites using a Kruskal-Wallis test followed by a Dunn's test for pairwise comparisons
- Non-parametric multivariate approach
  - All non-detects replaced with ½ average detection limit (DL) for each chemical
  - All analyses performed in R using the packages vegan (functions: *metamds*, *adonis*, and *betadisper*) and RVAideMemoire (function: *pairwise.perm.manova*)

Purpose	Statistical tool
Visually compare differences in CEC concentrations/signatures across sites	Ordination with non-metric multidimensional scaling (NMDS)
Assess differences in chemical signatures across sites	Permutational multivariate analysis of variance (PERMANOVA)
Ensure that differences across sites indicated by PERMANOVA cannot be attributed to data dispersion	Multivariate analog of Levene's test for homogeneity

Results- Personal care products (PPCPs)

- 44 different PPCPs (antidepressants, antibiotics, and other pharmaceuticals) detected across all sites in serum and/or gamete samples

- 22 different PPCPs detected in at least 25% of serum samples from at least one of the sites
  - Benztropine, DEET, hydrocortisone, and amitriptyline in at least 25% of samples at each site

- Sertraline, DEET, 10-hyrdoxy-amitriptyline were detected in at least 25% of all gamete samples from the St. Lawrence River
  - 8 PPCPs detected in milt and 14 PPCPs detected in eggs

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Results- PPCP concentrations

- PPCP concentrations in serum: 0.00208 (amsacrine; Lower Niagara) -130 ppb (hydrocortisone; Upper Niagara)
- PPCP concentrations in gametes: 0.00538 (desmethyldiltiazem; St. Lawrence milt) - 190 ppb (diphenhydramine, St. Lawrence egg)
- Highest concentrations of benztropine, DEET, and amitriptyline detected in all tissues from the St. Lawrence River, which also had the highest concentrations of the antidepressant sertraline
  - Significant differences in DEET concentrations in Detroit and St. Lawrence River
- Antibiotics more frequently detected in serum from sturgeon collected from the Detroit River and also generally had the highest concentrations

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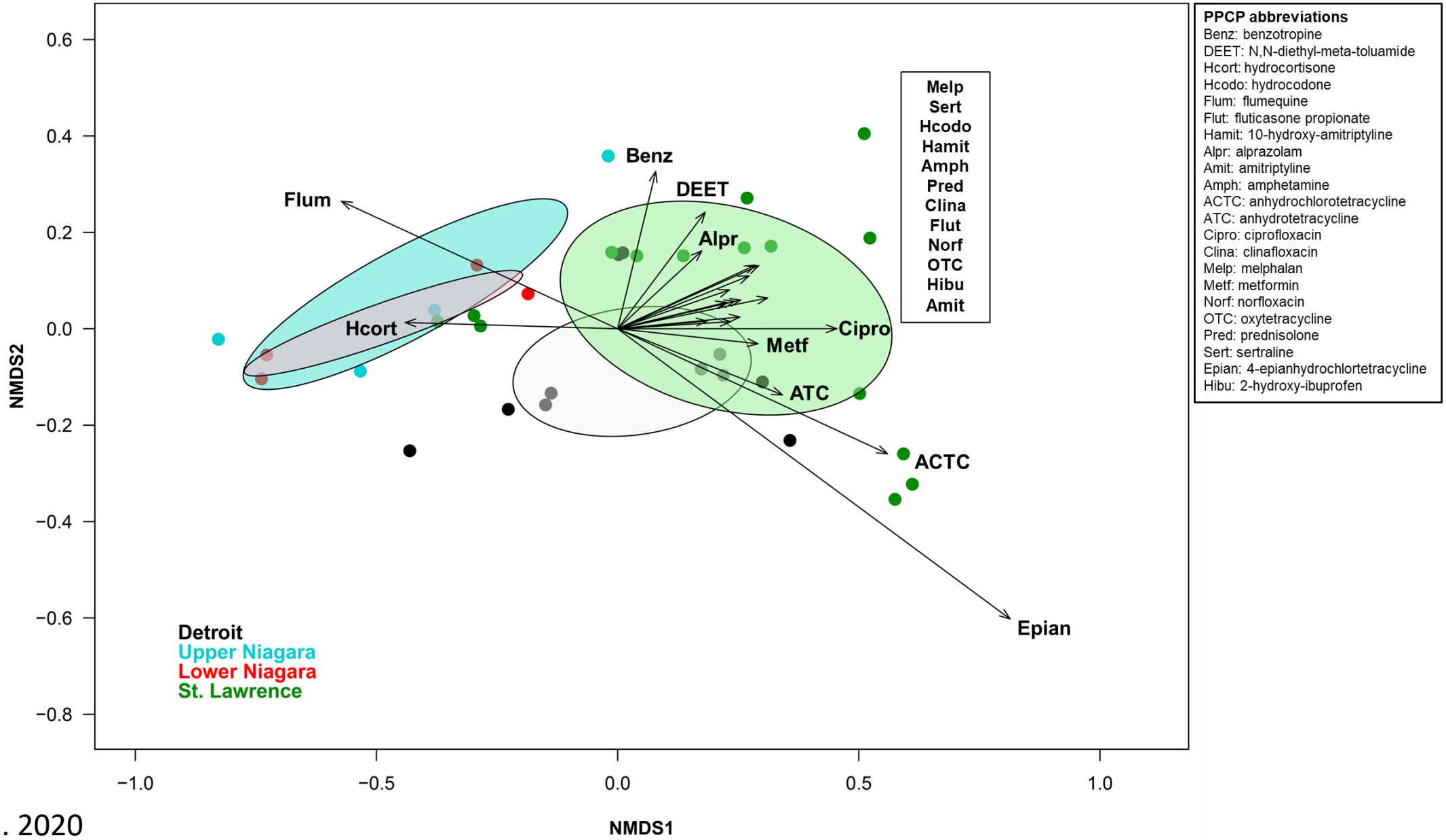
NMDS- PPCPs in serum



PPCP abbreviations
Benz: benzotropine
DEET: N,N-diethyl-meta-toluamide
Hcort: hydrocortisone
Hcodo: hydrocodone
Flum: flumequine
Flut: fluticasone propionate
Hamit: 10-hydroxy-amitriptyline
Alpr: alprazolam
Amit: amitriptyline
Amph: amphetamine
ACTC: anhydrochlorotetracycline
ATC: anhydrotetracycline
Cipro: ciprofloxacin
Clina: clinafloxacin
Melp: melphalan
Metf: metformin
Norf: norfloxacin
OTC: oxytetracycline
Pred: prednisolone
Sert: sertraline
Epian: 4-epianhydrochlortetracycline
Hibu: 2-hydroxy-ibuprofen

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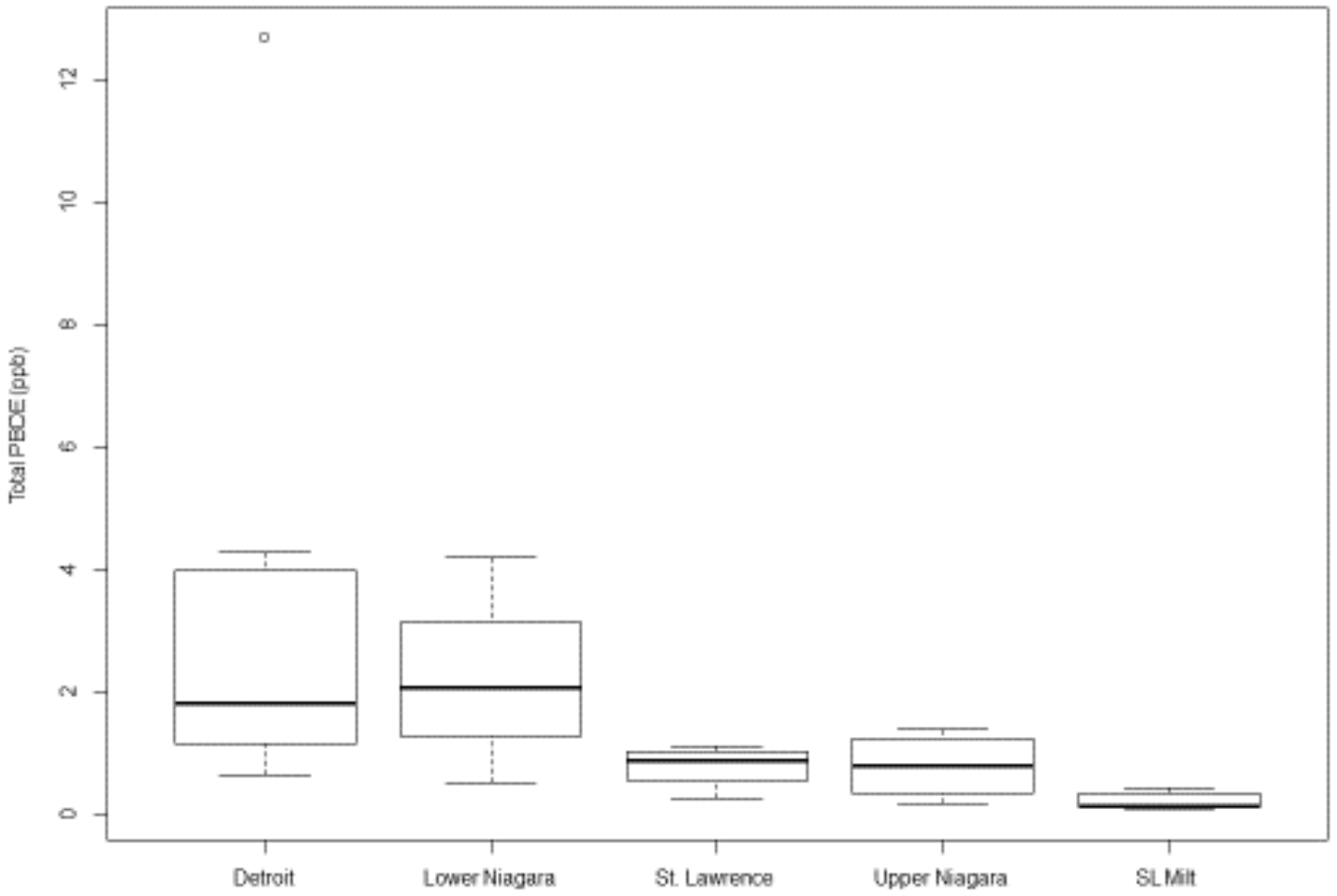
Results- Polybrominated diphenyl either (PBDE) concentrations

- Total PBDE concentrations in serum and gametes: 0.184 - 12.7 ppb and 0.0826 - 0.44 ppb, respectively
- 26 PBDEs found in serum in at least 25% of the samples at all four sites → 20 PBDEs were found in every serum sample at every site
- 24 PBDEs were detected in 25% of milt samples → 14 PBDEs were detected in all milt samples
- PBDE #47 had the highest mean and median concentration in serum at each site as well as milt from the St. Lawrence River
- NMDS revealed no obvious clustering of serum and no significant difference in site or sex with PERMANOVA



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Prevalence and potential effects of antibiotics and antidepressants

- Other research has identified antidepressants (specifically sertraline) and antibiotics in the tissues of various fish species collected from the Niagara River (Arnnok et al. 2017) → warrants exploration of possible effects

- Antidepressant effects on fish in existing literature
  - Predator avoidance and reproductive behaviors (Weinberger and Klaper 2014, Pelli and Connaughton 2015)
  - Altered development, growth, and behavior in early life stages (Pelli and Connaughton 2015, Huang et al. 2019)
  - Behavioral alterations in sturgeon → vulnerability to predation or collisions with boaters, affect ability to adequately feed, or alter opportunity for successful reproduction

Prevalence and potential effects of antibiotics and antidepressants

- Available studies suggest that antibiotics can also influence growth, development, reproduction, and behavior in fish (Zhang et al. 2015, Yan et al. 2016, Liu et al. 2018, Almeida et al. 2019)

- This study identified derivatives of tetracycline antibiotics in lake sturgeon tissues but data lacking regarding effects of antibiotic metabolites/degradants (Daghrir and Drogui 2013)

Additional considerations

- Seasonal variability (Jiang et al. 2011, Gray et al. 2020)

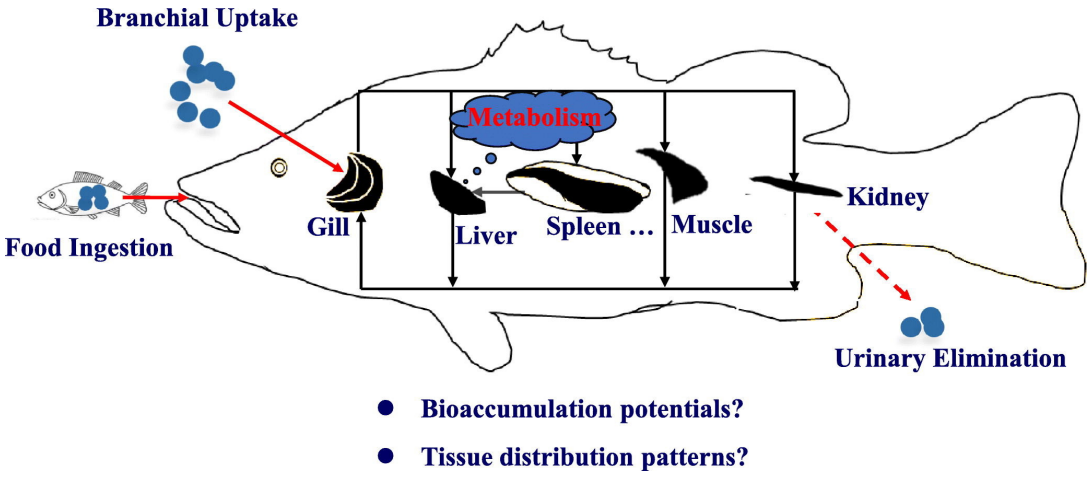
- Benztropine and DEET?
  - Detected in tissues at all sites
  - Limited (if any) information about effects

Distribution of PPCPs in lake sturgeon tissues

- Differences in the types of chemicals detected in serum and gametes
  - Sertraline detected in >85% of the gamete samples and in <10% of serum samples
  - 10-hydroxy-amitriptyline detected in eggs but not in serum

- Contaminants detected in gametes indicators of exposure and effects to the developing embryo and larvae (Birceanu et al. 2015, Sadoul et al. 2017, Thomas et al., 2018)?

- Bioaccumulation factors (BAFs) not determined in this study → could help with identifying fate and effects of antidepressants and antibiotics in fish tissues and organs

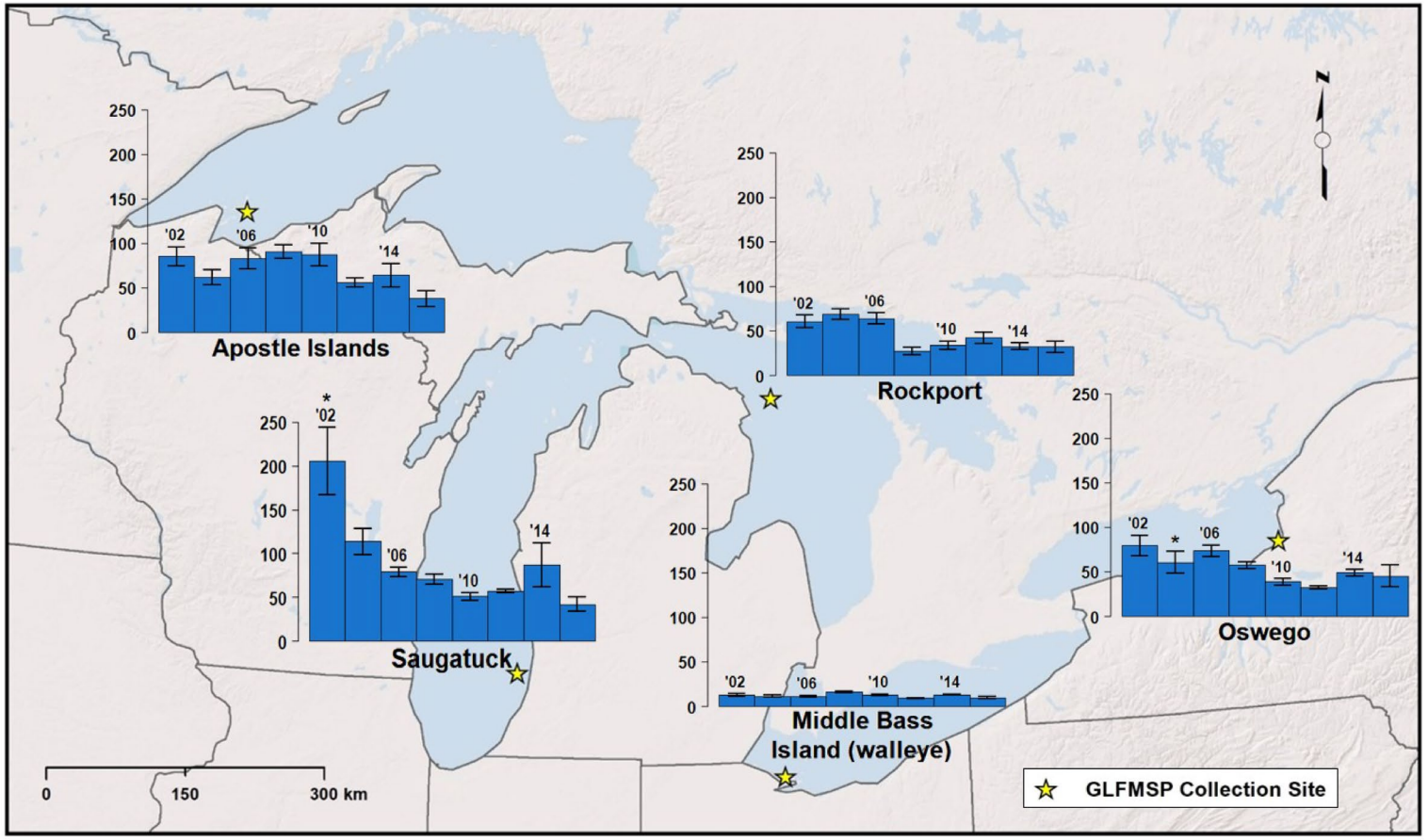


Liu et al. 2018

PBDE prevalence in lake sturgeon tissues and potential effects

- Previous work indicates PBDEs common in Great Lakes' fish tissues, including plasma (Valters et al. 2005, Crimmins et al. 2012, de la Torre et al. 2013)
- Reproductive, endocrine, developmental, and behavioral effects and mortality (Chou et al. 2010, Usenko et al. 2011, Yu et al. 2014, 2015)
- Disruption of thyroid hormone production (Noyes and Stapleton 2014) → effect lake sturgeon imprinting?

Mean Total PBDE (47, 99, 100, 153, and 154) Concentration in Lake Trout/Walleye from 2002 to 2016



EPA Great Lakes Fish Monitoring and Surveillance Program
https://www.epa.gov/sites/production/files/2021-02/documents/glfmsp_technical_report_2016.pdf

Management implications

- Areas with known sources of PPCPs and PBDEs (e.g., near wastewater treatment plants) not ideal for streamside rearing facilities, spawning reefs, or reintroduction programs

- If biological effects are observed in lake sturgeon or there is limited success with recovery efforts, managers may want to consider the potential for exposure to CECs

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